VOL. 10, NO. 3, FEBRUARY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

CHAIN-BASED ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS: A SURVEY

Haydar Abdulameer Marhoon[1, 2], M. Mahmuddin[2], Shahrudin Awang Nor[2]
[1]College of Sciences, Computer Department, UOKerbala, Iraq
[2]InterNetWorks Research Lab, School of Computing, College of Arts and Sciences Universiti Utara Malaysia, UUM Sintok, Kedah, Malaysia
E-Mail: haydar.a.alkafajy@ieee.org

ABSTRACT

In the last few years, wireless sensor networks (WSN) have become an active area for researchers due to its broad and growing application. However, routing is a critical issue that needs consideration as it directly impacts the performance of WSN. Several protocols have been proposed to address this issue as well as reducing energy consumption and prolong a lifetime of the sensor nodes in WSN. The chain-based is one approach from Hierarchical routing protocols which reduces the energy consumption in WSN. However, a problem arises when the chain has long-link (LL) from the base station (BS). This paper presents a comprehensive survey on chain-base hierarchical routing protocols, in terms of details, who to work, Phases, figures, and the main advantage and disadvantage for each protocol. Furthermore, the characteristics of chain-based routing protocols and the performance metrics that are used in WSN are discussed. Finally, this paper presents open challenges for researchers.

Keywords: wireless sensor network, routing protocols, chain-based, survey.

INTRODUCTION

Wireless Sensor Network (WSN) applications are widely used in several areas such as industrial, military, habitat monitoring, environment and disaster management (Sikander, 2013). The main elements of WSN are the sensor nodes that have many limitations in its characteristic like power resource, computational capability, bandwidth and memory (Gautam, Lee, & Pyun, 2009). These nodes have the capability to communicate each other and with one or more super nodes called the base station (BS).The base station may be connected to the Internet, and each node consists of: sensor for a specific task (one or more task). The sensor is consist of a radio module used to send data via a wireless medium, a micro controller for processing, and power supplier for provide the necessary energy for all components in the tiny device (Hadjila, Guyennet, & Feham, 2013a). Typically, batteries are the main power source in the sensor nodes and due to its ad-hoc deployment, recharging is a difficult task. WNS nodes also have some of level of intelligence algorithms to collect data and send it to the BS (Wei, Yang, & Gao, 2011).

Routing is one of the most important challenge issues that directly affected the performance of WSN. The main goal of the routing protocols in WSN is to develop efficient algorithms to reduce the power consumption and extend the life time of the network's nodes. There are many factors that can affect the performance of WSN. These include scalability, energy consumption, bandwidth, data aggregation, mobility, redundancy, multipath, end to end delay, network load, packet loss and localization (Salman, Shukla, Awasthi, Singhal, & Tripathi, 2014). There are also many hybrid routing protocols proposed to reduce the time for network partition and uniform the nodes energy distribution. MOHRA proposed to selected the right path to the sink base on multi-objective metrics like control over head, total energy consumption, HOP count, LQI, reaction time (Kulkarni, Prasad, & Prasad, 2013)

Depending on the network structure, the routing protocols in WSN are divided into three types: flat, hierarchical, and location-based routing protocols. In flat routing protocols, all nodes perform the same task in the network and normally use flooding to transmit data to the BS. The flat topology is effective in the small-scale networks. Location-based routing protocols used some real time applications, also call position-based to transmit data depending on the geographical positions. In hierarchical routing protocols, nodes perform different task. Cluster head (CH) in one or two in every cluster and main function of CH is data processing and massage transmission between CHs or with the BSs, the rest of nodes calls ordinary nodes (ONs) or member nodes (MNs) that perform the sensing and transmit the data to the CH (Liu, 2012a) (Devika, Santhi, & Sivasubramanian, 2013).

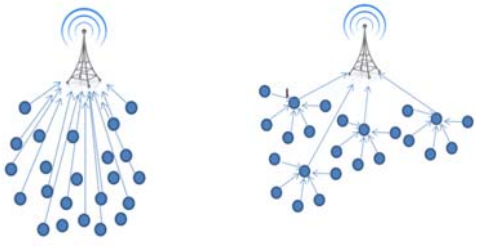

Figure-1. Non-clustering vs clustering.

Cluster-based, chain-based and tree-based protocols are main categories of hierarchical routing protocols (Zhang, Wu, Ren, He, & Lin, 2010). In Cluster-Based protocols, one or two node are selected to be CH and other nodes connected to closest CH as a MNs.. Examples of cluster-based protocols include LEACH (Heinzelman, Chandrakasan, & Balakrishnan, 2000), TL-

LEACH, HEED, PEACH, DWEHC, USC, and TEEN. while the principal concept in Tree-Based is all sensing data is sent only from children (sensor node) to its parent (Liang, Wang, & Chen, 2009). An example of the tree-based routing protocol is DRINA (Villas et al., 2013), while Nodes in a chain-based protocol are arranged in a chain-like topology where one of the nodes functions as a CH to transmit to the BS (Liang et al., 2009). In this paper, different routing protocols topology are discussed in the literature review, Chain-Based show more promising than the others (Mamun, Ramakrishnan, & Srinivasan, 2010)(Mamun, 2012).

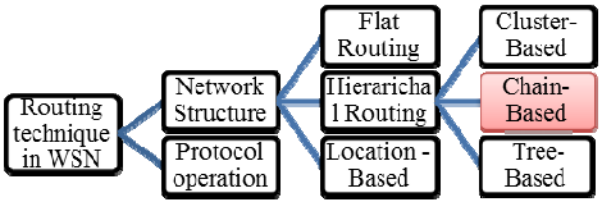

Figure-2. Routing technique in WSN.

Data reporting and sensing in a wireless sensor network depend on the time criticality on specific application that is being used. Data sensing and reporting can be classified into event-driven, time-driven, query-driven and hybrid which directly affect power consumption and routing stability (Raghunandan & Lakshmi, 2011). Nodes deployment can be divided into those based on grid and based on continued points (Liu, 2012b)..

There are several survey papers on hierarchical routing techniques that present some of the popular routing protocols. This paper attempts to survey the chain-based routing protocols only, started with PEGASIS then nine chain-based routing protocols are presented and highlight in details, figures, and some of advantage and disadvantage for each protocol then some of the important chain-based characteristics, finally conclusion and open issues for the WSN researchers.

RELATED WORKS

Many papers on WSN are presented by researchers in the recent years. Liu in (Liu, 2012a) presents a comprehensive survey paper on hierarchical (clustering) routing protocols in WSN. The survey addresses the protocols base on classification of different stages and summarizes the previous surveys on routing algorithms in WSN. Liu also highlights the core contributions and listed 16 clustering routing protocols in detail. Liu further explained the features, advantages and disadvantages of the chain concept. Sikander et al. in (Sikander, 2013) presented cluster-based routing schemes in WSN. The survey focuses on three main types of clustering routing schemes, namely chain, grid and block. Their study, they surveyed on the PEGASIS, CCS, and TSC protocols. The author also surveyed the grid-based protocols such as GAF, PANEL, TTDD, HGMR and SLGC. Sikander et. al also reviewed block-based protocols such as LEACH, HEED and USC, and discusses the advantages and disadvantages of each protocol. They also discuss issues such as CH calculation, selection, changes in topology and network expandability.

An energy efficient routing protocol is discussed by Rahman et al. in (Rahman, Anwar, Pramanik, & Rahman, 2013). The paper classified the routing protocol into six categories in WSN namely: data relaying protocol, data centric protocols, hierarchical protocols, location-based protocols, mobility-based protocols and heterogeneous protocols.

Devika et al. in (Devika et al., 2013) classified the routing techniques into two types according to network structure and operation protocols. The network structure can be divided into three categories which are flat, hierarchical, and location-based routing protocols. The operation protocols are divided into negotiation-based, multipath, query-based, QoS-based and coherent-based routing protocols. The authors summarized routing protocols in a table. Heterogeneous routing protocols in WSN are presented by Katiyar et al. in (Katiyar, Chand, & Soni, 2010).

PERFORMANCE METRICS

Many metrics are used by the researchers to evaluate the performance of any protocol in wireless sensor networks (Mamun, 2012):

- Energy consumption: these metric computed by adding all power consumption in each node in the network.
- Energy distribution: these metric compute how the evenly power dissipated in all nodes.
- Network lifetime: it is the mean time the first node or last node die, or time till the network disconnected or time to how many packets are received by the sink before exceeding threshold.
- Scalability: means how this network performs with the number of networks nodes growing
- Routing message cost: these metric use to evaluated the efficiency of the algorithm, number of packet generated in each successful communication.
- Route length: It count the number of nodes from source to destination.
- Control overhead: the ratio for control message with data message being sent in the network.
- Message loss: the percentage of how many massages are not received by any sensor nodes.
- Latency: important metrics to measure the average delay between sending a message and receiving it by the sink.
- Storage requirement: the memory required by a protocol in each node.

CHAIN-BASED ROUTING PROTOCOLS IN WSN

These are several algorithms developed in chain-based routing protocols:

1. Power-efficient gathering in sensor information systems

PEGASIS protocol begins the chain-based approach concept for routing protocols in the WSNs. During initialization the chain construct starts from the furthest node in the topology and starts to communicate with only closest neighbor. All nodes use the greedy algorithm to organized themselves as a chain. The greedy algorithm considers only the physical distance for selected next hop in every node and ignores the residual energy in the neighbor that causes short node lifetimes. Alternatively the BS can calculate the chain after broadcast the chain information to the all sensor node in the network. Every 100 rounds, the chain leader (how it connects to the BS) will be changed from node to other randomly. The strong point in this randomizes to insure first dead nodes are randomly location in this network. Moreover, if the chain head death the network starts new chain construction and select a new chain head randomly(Madhumathy & Sivakumar, 2012) (Lindsey & Raghavendra, 2001).. Normal topology for PEGASIS is show in Figure-3.

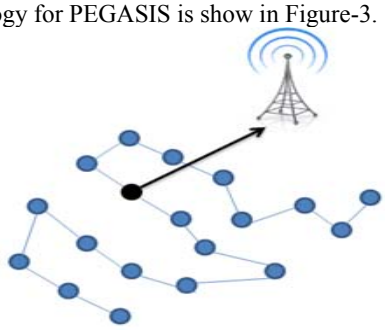

Figure-3. PEGASIS protocol topology.

However, in the first improvement on chain leader (or chain head) selection coming from same authors when make threshold on the neighbors distance to make sure this leader not have only few energy instead of try to reduce the neighbor distance in some way(Lindsey, Raghavendra, & Sivalingam, 2002).

PEGASIS used the same radio model was used in LEACH protocol which is first order radio model. In first order model the energy for received or transmitted data is E_{elec}= 50nJ/bit and the energy dissipates in the amplifier is E_{amp}=100pJ/bit/m^2. So the equations (1) and (2) used to calculate the energy costs for k-bit in transmit and receive as below (16) (28)(84):

For transmitting

$$E_{TX}(k,d) = E_{TX\text{-}elec}(k) + E_{TX\text{-}amp}(k,d) \quad (1)$$

$$E_{TX}(k,d) = E_{elec} * k + E_{amp} * k * d2$$

For receiving

$$E_{Rx}(k) = E\_(Rx_{elec})(k) \quad (2)$$

$$ERx(k) = Eelec * k$$

PEGASIS have important advantage in terms of power saving, that is coming from reducing the clustering overhead energy in every round and make sure that every node connected with only neighbor so this procedure will reduce power consumption through radio signal part. Moreover, every node in PEGASIS fuse the neighbor data with its data to reduce the amount of data transfer to BS, according to equations 1 and 2 this fusing will reduce energy cost in both side (receiving and transmitting).

However, PEGASIS have some drawbacks first it is assuming that all nodes can directly be connected with the BS, while, in practical these nodes use multi-hops to reach the BS. Second PEGASIS used greedy algorithm to construct its chain, which it used distance parameter to selected next hope connection, it is like traveling salesman problem and greedy doing good performance in some cases(Ganesh & Amutha, 2013). However, greedy make long distance connection in the different topologies and this will make some nodes depleted its energy quickly, second issue in greedy, it is use distance only to choose the next hop connection without consideration of remaining energy in this node, this cause some of weak point in the chain may be will disconnected some of nodes from the chain. Furthermore PEGASIS is not suitable for deterministic deployment topologies because of the long chain disadvantage coming with single chain construction.

2. Chain-cluster based mixed routing

CCM take the low power advantage from PEGASIS protocol, and short transmission delay from LEACH protocol, CCM protocol has two phases, Phase 1 is known as chain-based routing. In this step, thesensor nodes construct a chain for the intra-connection and all chain member nodes send data to the chain head using chain-based routing concept. This process involves two steps namely Selection of chain head node and Data transmission in a chain. In Phase2, the CCM have two steps namely Voting cluster head and Data transmission in the cluster. All chain heads construct a cluster-based routing as inter-connection. Finally the voted cluster head send fused data to the Base Station (Tang, You, Guo, Guo, & Ma, 2010). If the cluster head is a far away from the base station more energy will be used to send data (Nokhanji & Mohd Hanapi, 2014).

CCM in Figure-4 can mitigate the power consumption by the uniformity deployment for the sensors and combined the advantage from LEACH and PEGASIS. However, it ignores the energy consumption coming by long distance between chains, also the delay that is coming with long link.

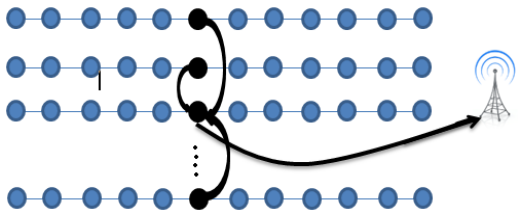

Figure-4. CCM routing protocol.

3. Chain routing based on coordinates-oriented cluster

CRBCC divided the network topology into many Y coordinator clusters with equal number of nodes

(approximately), and then it used the simulated annealing algorithm instead of greedy algorithm in PEGASIS to build the intra-connection as chain form in every cluster. Every chain elected a leader in X coordinator and these leaders constructed the main chain by also using simulated annealing SA algorithm. Then once the leader of leader chain node selected randomly it sent data to the base station directly (Zheng & Hu, 2009)(Gengsheng, Xiaohua, & Xingming, 2009). Figure-5 show CRBCC topology.

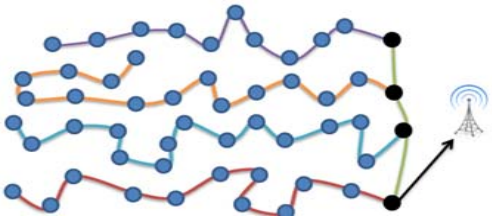

Figure-5. CRBCC routing protocol.

CRBCC reduces the data delivery time from nodes to BS. This is achieved by dividing the chain in PEGASIS to multi parallel chains depending on horizontal positions (avoid Long Link problem). Although depending on chain-based approach it minimizes the power consumption in data aggregation. Greedy algorithm used in PEGASIS is locale search and it is not provide global optimum link between nodes so, CRBCC used another heuristic algorithm for this issue.

However, CRBCC has some of important drawbacks in term of chain leader election in the top of chains; moreover these nodes will deplete its energy quickly than others without any active procedure to select another chain leader during the network lifetime. Although, randomly selection for the main head caused unlucky nodes selected twice or more than twice compared with others that never selected, randomize selection can replaced by choosing effective parameters like rest energy or node distance with base station these parameters can make leader selection more efficient and prolong the network lifetime.

4. A reliable and energy-efficient chain-cluster based routing protocol

REC+ protocol aims to perform the maximum reliability in a multi hop network by calculating the best position for the CH and the proper shape and size of the cluster. REC+ is the first protocol that considers transmission reliability, energy efficiency, and intra-cluster delay together to build the cluster and select the cluster head.

The operation of REC+ is divided into three phases (Taghikhaki, Meratnia, & Havinga, 2013).: first Cluster Formation phase, in this phase REC+ assume that the BS have all information about nodes in term of position and energy, then BS will divided the sensor nodes in the network into clusters according to Y-coordinator Figure-6 shows one of these clusters.

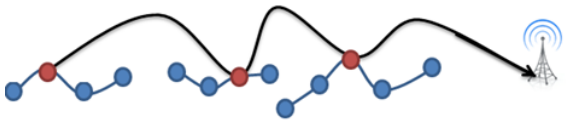

Figure-6. REC+ routing protocol.

Second, Cluster Head Selection and Chain-Cluster forming phase, opposite on other algorithms, REC+ choose the chain heads first then assign its members nodes. BS selected CHs base on residual energy divided by initial energy. Hop-by-hop reliability (HHR) reported to the BS by nodes to ensure quality link created, and this node will be the first node into this cluster if EER (end-to-end reliabilities) is more than the threshold 0EER. Nodes play multi hop (chain) method to reach its CH, and another threshold apply to avoid long ling (LL) in every cluster-chain which is 0delay this is second threshold prevent delay in the LL. Furthermore, Relay Nodes (RNs) are assigning to some powerful nodes (in term of energy and position) by BS to relay CHs data if this CH cannot directly send its data to the next CH (next hop). To select proper RN, BS calculate the maximum Power Level (PL) for every CH that can used for coverage then assign RN for this CH if this necessary for it. All BS calculations will be repeated if any node dies during the network lifetime.

Third phase in REC+ is steady state phase, in this phase every node will sensing data and send to its neighbor, this node fuse the neighbor data with its data (if any) then deliver to CH, CHs used RNs to ensure this data reach BS in reliable way. If there is any significant changes accrued in nodes parameters can affected link quality or some nods below the threshold 0EER , the BS recalculate CHs and clusters shape as well as.

The advantage of REC+ is by using tow threshold to create cluster and select the CH, one for energy and another for delay. However, REC+ make many more overhead on the network during it three phases, moreover REC+ assuming all nodes can connected directly to the BS to setup the first and second steps and this is not always can applicable in practical networks. The important notice for REC+ there is in random deployment a lot of nodes may be allocated in the specific area this is causes some of clusters have many nodes and other a few nodes if Y-coordinator still used to clusters created.

5. Balanced chain-based routing protocol

BCBRP decrease the energy consumption in the network by partitions the network area into small equal sub area, since the number of the sub-area equal j2 (j= 1,2,3,….) . After that BCBRP assign header and leaf nodes in every sub-area. Nodes location in bounder of this sub-network, furthermore leaf node make connection between its sub-network and previous sub-network while, header nodes make connection between its network with next sub-network (with notice that first sub-network don't have leader node and last sub-network don't have leaf node). After that in every sub-area chain will constructed by

using minimum Spanning tree algorithm instead of greedy in PEGASIS to ensure there is minimum chain distance will construction in each network (Ahn, Kim, Sim, Youn, & Song, 2011). Figure-7 show BCBRP chain construction in four sub-networks.

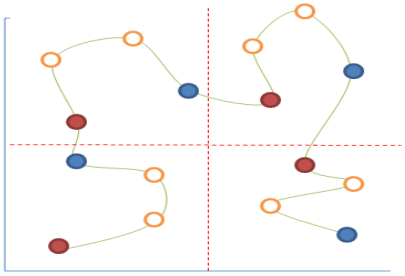

Figure-7. BCBRP routing protocol.

If any node death accrues during network lifetime, only this sub-network will take chain reconstruction. Moreover the main head node (who is connected with BS) selected randomly from the larger sub-network in the sensing area.

BCBRP is reducing the power consumption by minimized the overall chain link with minimum Spanning tree algorithm instead of greedy which have many drawbacks. However, single chain in BCBRP and randomly selecting for the main head are very important drawbacks that can affected the performance of this protocols.

6. Rotation PEGASIS-based

RPB is combined the advantage of PEGASIS with GAF (Geographical Adaptive Fidelity) in one protocol. RBP consist of three stages which are link establishment, leader selection and data transmission. In link establishment phase distance threshold factor will be control link construction. Link start from the farthest node in the sensing area, every node will check the distance with its neighbor with distance threshold if more than threshold, the node connected directly by sending request connection message and waiting to receive conformation message. If the distance less than or equal distance threshold this node going to sleep mode in this round and be sure wake up before next round coming and rotate this role with the neighbor node(Yang, Mao, Yu, & Leng, 2013).. Figure-8 show chain build by RPB protocol with sleep nodes.

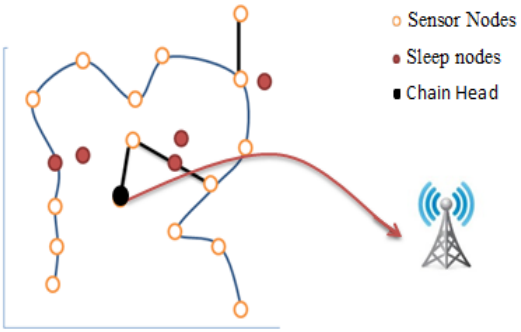

Figure-8. Chain constructing by RPB protocol.

Second phase is for chain leader selection, RPB selected leader node depend on residual energy and distance with base station with two specific weight w1 and w2 to control efficient selection for chain leader as show in equation 3.

$$Qi = W1 * Ei + W2 / d_{BS}(i) \quad (3)$$

Where Qi is comparative factor used by base station to select chain leader, Ei is the residual energy of the i node, d_{BS} is the distance between node with BS and W1, W2 are weighted variables to make sure the efficient selection for chain leader and W1+ W2=1 and always W2 > W1 to give some priority for distance factor.

Third phase is Data Transmission phase, every node will decrease its energy radio transmission to hear only closest neighbor node. RPB use Token mechanism to start data collection from all nodes. Token packets are very small and take very few energy to process and transmitted along chain member. Like PEGASIS each nodes receive data from its neighbor fuse with its data and forward the fused data to next hop until reach chain head, chain head fusing all network data and deliver to base station in the end of each round.

During some nodes are very nearest each other because of the randomly deployment, RPB has advantage when make distance threshold and using sleep mode for this nodes to save their energy in this round. Another advantage in RPB is when selected the chain head by considering both residual energy and distance with base station and putted some priority for distance.

However, RPB has disadvantage when it loss the sleeper coverage range along round time and overhead caused by selection sleeper nodes. Also this authors not enough explanations about methodology to calculate distance threshold.

7. Chain-based 1 & Chain-based 2

Chain-Based1 routing protocol deployed all nodes randomly in the sensing area. Multi chain directed to the base station is created from the last node to the first node as show in Figure-9a (divided sensing area into m sub-areas according to X coordinator). All nodes on the top chain will be chain heads and using single hop to reach

the base station. Chain will update if any node deplete its energy during the network lifetime. Every node sensing data and transmit to the closest neighbor, moreover this node fused data with its data and send it to next hop till reach base station.

Chain-Based2 is an improvement of the Chain-Based1 protocol. It has the same concept in the intra-connection and doing the same deviation in Chain-Based1, except it is created main chain from all chain heads as show in Figure-9b. At first the nearest node (in the main chain) from BS is responsible to sending all network data to the base station, then during the **network** lifetime node that's have more energy will play as main head and connected with the BS (Hadjila, Guyennet, & Feham, 2013b).

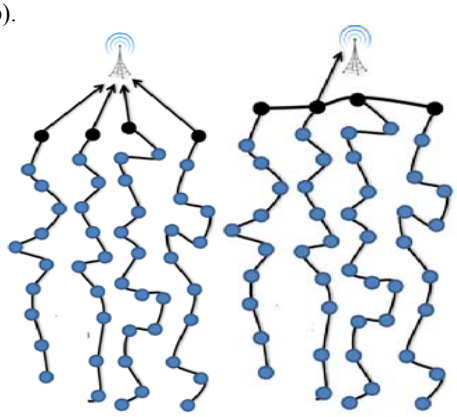

Figure-9. (a) Chain-based1 routing (b) Chain-based2 routing protocol.

The main advantages of both protocols are coming from the multi chain concept. Reducing delay and saving nodes power as well as prolong network lifetime are very important things in WSNs. However random deployment have not guarantee to evenly distributions for nodes in sensing area and that's mean some of chains have more nodes than others so, this can directly affect network performance.

8. Position-based chain cluster routing protocol

PCCR protocol in Figure-10 is proposed for narrow strip area application in WSN where the traditional routing protocol cannot apply (in strip WSN). This area is divided into belt-shape region cluster where every region selects a cluster head depending on position and residual energy. These CHs then create the chain as a backbone of the strip. PCCR have four phases: (1)Cluster Divided Phase, (2) Cluster Head Elect Phase, (3)Cluster Head Chain Establishment Phase, and (4) Steady-State Phase (Qiao & Zeng, 2011).

This protocol can prolong the lifetime for the network by saving the CHs energy especially for the farthest cluster by creating the backbone (as a chain). In this way the CH does not suffer from energy exhaustion when transmitting its data. Data will be forwarded to the next hop only. However it is for special area only and more delay will happen in the long chain in the narrow strip. Additional processes will occur if this happens.

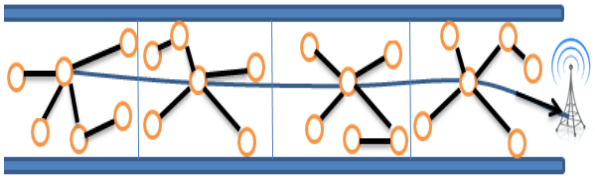

Figure-10. PCCR routing protocol.

9. Grid-PEGASIS routing protocol

Grid-PEGASIS scheme is improved on PEGASIS protocol in term of energy efficient and energy balancing. It is created to prevent the long hop causes by greedy algorithm by divided sensing area into small grid area and this scheme has many assumptions before starting that is (1) all nodes in the network and BS are stationary. (2) The sensing area is divided into small grids and every grid has unique ID, (3) each node has unique ID also and it is knows its Grid ID, (4) all nodes send data periodically and they are homogeneous (Huang, Chen, Wang, Lin, & Chen, 2010).

Grid-PEAGASIS after dividing area into small grids and every grid has some of nodes is assigns start node and end node in every grid. Functionality of start node to connected with next grid by end node. Furthermore Grid-PEGASIS has been applied in three types of topology that Deterministic Topology (DT), Intra-Grid random (IGR) and random deployment. In DT the nodes will install in specific predetermine location while, in IGR sensing area will divided into specific grids and nodes are randomly deployment in the each grid and so on Figure-11 show IGR according to Grid-PEGASIS protocol.

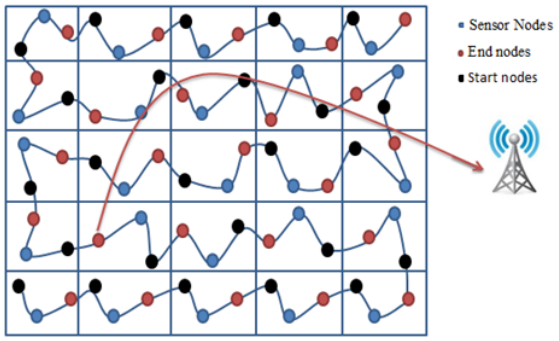

Figure-11. IGR according to Grid-PEGASIS protocol.

Then, in each grid chain will construct by using greedy algorithm and chain head will be selecting in the same way in PEGASIS by apply equation (4) (since i is current round and N is number of nodes in this network) to make sure the random location for CH in the topology and this can assist to make balancing for power consumption in CH.

$$CH=i \bmod N \quad (4)$$

The advantage of this protocol is avoiding long next hop link happen in some nodes with PEGASIS. However, main disadvantage of Grid-PEGASIS protocol is coming from single chain construction through a lot of nodes, delay and redundant data cannot avoid in these protocols during too long link. Methodology to select start and end nodes is not explained. Furthermore, randomly choosing for chain head will cause many problems in term of distance between base station with chain head and energy for this node are two important factors not considered by this protocol.

All of these protocols working under the same concept of chain based routing. The main idea in chain approach to make sure the ordinary nodes are connected with the closest nieghbour only. Therefore, this paper can consider chain based routing protocols is more efficient approach among all types of routing protocols in WSNs, Table-1 shows more details for these protocols.

Table-1. Comparative study of routing protocols in WSNs.

Protocol	Authors year	Intra/ inter Cluster routing	Performance metrics	Tools	Advantage	Disadvantage
PEGASIS	Lindsey, et al. (2002)	Multiple-hop / Single-hop	Nodes Death	C Simulation	1. Reducing the clustering overhead by chain method. 2. Reduce power consumption 3. Reduce the amount of data transfer to BS	1. Assuming that all nodes can directly be connected with BS 2. Using only distance to selected next hope by greedy 3. It is not suitable for deterministic deployment
CCM	Tang, et al. (2010)	Multiple-hop / Multiple-hop	Energy* Delay	SWANS	1. Deterministic deployment with chain-based approach is applied. 2. Low overhead on the network. 3. Low delay in cluster part.	1. Conserved more energy in cluster part. 2. Using sequential CH selection. 3. Using residual Energy only to select main head.
CRBCC	Zheng, et al (2009)	Multiple-hop / Multiple-hop	Energy Consumption, Delay	Not Specified	1. Reducing data delivery time from nodes to BS. 2. Minimizes the power consumption in data aggregation by using global search algorithm (SA).	1. Chain leader election in the top of chains and these nodes will deplete its energy quickly than others 2. Randomly selection for the main.
REC+	Zahra, et al (2013)	Multiple-hop / Multiple-hop	Energy*Delay	Java JDK6	1. Using tow threshold to create cluster and select the CH, one for energy and another for delay. 2. using relay node to reduce power between CHs.	1. High overhead. 2. It is assuming all nodes can connected directly to the BS. This is not always can applicable in practical networks.
BCBRP	Ahn, et al (2011)	Multiple-hop / Multiple-hop	Network lifetime	Not specified	1. Minimized the overall chain link with minimum Spanning tree algorithm. 2. A void long link by divided sensing area into sub-area.	1. Single chain caused more delay. 2. Randomly selecting for the main head. 3. Randomly deployment is not always applicable with equal dividing area.
RPB	Yang, et al (2013)	Multiple-hop / Single-hop	Network Lifetime	MATLAB	1. Distance threshold for next hop connection 2. Using sleep mode. 3. Selected the chain head by considering both residual energy and distance.	1. It loss the sleeper coverage range along round time and 2. Overhead caused by selection sleeper nodes. 3. Methodology to calculate distance threshold not clear.
Chain-Based1 Chain-based2	Hadjila, et al (2013)	Multiple-hop / Single-hop Multiple-hop / Multiple-hop	Power Consumption and number of alive nodes	MATLAB	1. Using multi chain concept to reducing delay and redundant data 2. Saving nodes power. 3. Prolong network lifetime	1. Random deployment have not guarantee to evenly distributions for nodes. 2. Multi CHs without adaptive way to rotate role of CH reduced lifetime.
PCCR	Qiao, Zeng (2011)	Multiple-hop / Multiple-hop	Life cycle	MATLAB	1. Prolong the network lifetime of all nodes. 2. keep energy for far cluster	1. Designed for specific area 2. Not suitable for expandable
Grid-PEAGASIS	Yung et al 2010	Multi-hop/Multi-hop	Network lifetime	Not mention	1. Avoiding long next hop link happen in some nodes with PEGASIS.	1. Single chain construction. 2. Delay and redundant data cannot avoid 3. Method is not explained. 4. Randomly choosing CH

CHAIN-BASED ROUTING PROTOCOLS CHARACTERISTICS

There are many common characteristics for the hierarchical routing protocols. However, it can be concluded that some are specifically for chain-based RP-

Every node in the network is connected with the closest neighbor node only in a chain form.

- Connection type in intra-connection is multi-hop, on the other hand inter-connection use single or multi hop until reach a BS.
- Extendable of network lifetime with low power consumption.
- Reducing the overhead coming from dynamic cluster formation.
- Some protocols assume that all nodes can send Hello massage to the BS in first round to collect all nodes information
- Chain-based network structure suffers from delay caused by Long Link (LL) and data redundant (repetition of data transmitions).
- Division of Long Link (long chain) into sub-level of small chain is good idea to avoid data redundancy.
- Residual energy is not considered when select CH in some protocols, while others consider this as CH selection condition.
- Base Station is stationary and there exists only one base station in all protocols.
- Compared with cluster based protocols, in chain-based can reduce the energy consumption when nodes send data only to its closest neighbor.
- Energy distributions in chain-based routing protocols are even due to little energy per bit used for communication

CONCLUSIONS

Wireless sensor networks applications have been widely used in the last decade Therefore, it is important that efficient and secure routing protocols are required for making sure of safe data delivery and prolonging the lifetime of sensor nodes. Many researchers have developed different routing protocols in WSNs. Depending on the network structure, chain-Based is one of the important types that can reduce the power consumption and prolong the lifetime for the network In this paper some of chain-based routing protocols in WSN in term of the details, figures, phases, advantage and disadvantage is discussed.

The characteristics and some of the important performance metrics of chain-based routing protocols are explained. Furthermore, chain construction becomes the key factor to differentiate between these protocol, greedy algorithm, simulated annealing, ACO algorithm, spanning, and so on. After chain construction, the chain head selection also varies from protocol to another. Some of them randomly selects without considering the residual energy and results in shorter node lifetime. In other hand when the protocols using node position and remaining energy to select CH the lifetime and number of live sensor will be increase because of the balancing of the power dissipation.

Chain construction, node deployment, chain head node selection, scalability, coverage area, energy consumption, location awareness, nature of environment, WSN Applications, control message and QoS still open challenges for researchers when developing new protocol in WSNs.

REFERENCES

Ahn, K. S., Kim, D. G., Sim, B. S., Youn, H. Y., & Song, O. (2011). Balanced Chain-Based Routing Protocol (BCBRP) for Energy Efficient Wireless Sensor Networks. 2011 IEEE Ninth International Symposium on Parallel and Distributed Processing with Applications Workshops, 227–231. doi:10.1109/ISPAW.2011.71.

Devika, R., Santhi, B., & Sivasubramanian, T. (2013). Survey on Routing Protocol in Wireless Sensor Network. IJET, 5(1), 350–356.

Ganesh, S., & Amutha, R. (2013). Efficient and Secure Routing Protocol for Wireless Sensor Networks through SNR Based Dynamic Clustering. COMMUNICATIONS AND NETWORKS, 15(4), 422–429.

Gautam, N., Lee, W.-I., & Pyun, J.-Y. (2009). Track-Sector Clustering for Energy Efficient Routing in Wireless Sensor Networks. 2009 Ninth IEEE International Conference on Computer and Information Technology, 116–121. doi:10.1109/CIT.2009.130.

Gengsheng, Z., Xiaohua, L., & Xingming, H. (2009). The research of clustering protocol based on chain routing in WSNs. 2009 Asia-Pacific Conference on Computational Intelligence and Industrial Applications (PACIIA), (1), 292–295. doi:10.1109/PACIIA.2009.5406433.

Hadjila, M., Guyennet, H., & Feham, M. (2013a). A Chain-Based Routing Protocol to Maximize the Lifetime of Wireless Sensor Networks. Wireless Sensor Network, 05(05), 116–120. doi:10.4236/wsn.2013.55014.

Hadjila, M., Guyennet, H., & Feham, M. (2013b). A Chain-Based Routing Protocol to Maximize the Lifetime of Wireless Sensor Networks. Wireless Sensor Network, 05(05), 116–120. doi:10.4236/wsn.2013.55014.

Heinzelman, W. R., Chandrakasan, A., & Balakrishnan, H. (2000). Energy-Efficient Communication Protocol for Wireless Microsensor Networks. In: Proceedings of the 33rd Hawaii International Conference on System Sciences (Vol. 00, pp. 1–10).

Huang, Y.-F., Chen, C.-L., Wang, N.-C., Lin, J.-Y., & Chen, C.-M. (2010). Performance of a data gather scheme with novel chain construction for wireless sensor networks. Proceedings of the 6th International Wireless Communications and Mobile Computing Conference on ZZZ - IWCMC '10, 1208. doi:10.1145/1815396.1815673

Jang, S., Kim, H., Kim, N., & Chung, T.-M. (2011). Energy-Efficient Clustering Scheme with Concentric Hierarchy. In IEEE (pp. 79–82).

Katiyar, V., Chand, N., & Soni, S. (2010). Clustering Algorithms for Heterogeneous Wireless Sensor Network : A Survey. International Journal of Applied Engineering Research, Dindigul, 1(2).

Kulkarni, N., Prasad, N., & Prasad, R. (2013). MOHRA: Multi Objective Hybrid Routing Algorithm for Wireless Sensor Network. Wireless VITAE 2013, 1–6. doi:10.1109/VITAE.2013.6617056.

Liang, J., Wang, J., & Chen, J. (2009). A Delay-Constrained and Maximum Lifetime Data Gathering Algorithm for Wireless Sensor Networks. 2009 Fifth International Conference on Mobile Ad-Hoc and Sensor Networks, 148–155. doi:10.1109/MSN.2009.62.

Lindsey, S., & Raghavendra, C. S. (2001). PEGASIS : Power-Efficient GAthering in Sensor Information Systems '. IEEE, 1125–1130.

Lindsey, S., Raghavendra, C., & Sivalingam, K. M. (2002). Data Gathering Algorithms in Sensor Networks Using Energy Metrics. IEEE TRANSACTIONS, 13(9), 924–935.

Liu, X. (2012a). A survey on clustering routing protocols in wireless sensor networks. Sensors (Basel, Switzerland), 12(8), 11113–53. doi:10.3390/s120811113.

Liu, X. (2012b). Sensor Deployment of Wireless Sensor Networks Based on Ant Colony Optimization with Three Classes of Ant Transitions. IEEE Communications Letters, 16(10), 1604–1607. doi:10.1109/LCOMM.2012.090312.120977.

Madhumathy, P., & Sivakumar, D. (2012). A Comparative Analysis of clustering based Routing Techniques for WSN. International Journal of Scientifc & Engineering Research, 3(10), 1–5.

Mamun, Q. (2012). A Qualitative Comparison of Different Logical Topologies for Wireless Sensor Networks. Sensors (Basel, Switzerland), 12(11), 14887–913. doi:10.3390/s121114887.

Mamun, Q., Ramakrishnan, S., & Srinivasan, B. (2010). Multi-chain oriented logical topology for wireless sensor networks. 2010 2nd International Conference on Computer Engineering and Technology, V2–367–V2–372. doi:10.1109/ICCET.2010.5485489.

Nokhanji, N., & Mohd Hanapi, Z. (2014). A Survey on Cluster-Based Routing Protocols in Wireless Sensor Network.pdf. Applied Sciences, 2011–2022.

Qiao, G., & Zeng, J. (2011). A Position-Based Chain Cluster Routing Protocol for. SPRINGER, 189–194.

Raghunandan, G. H., & Lakshmi, B. N. (2011). A comparative analysis of routing techniques for Wireless Sensor Networks. 2011 National Conference on Innovations in Emerging Technology, 17–22. doi:10.1109/NCOIET.2011.5738826.

Rahman, A., Anwar, S., Pramanik, I., & Rahman, F. (2013). A Survey on Energy Efficient Routing Techniques in Wireless Sensor Networl <. In ICACT (pp. 200–205).

Salman, Shukla, S., Awasthi, S., Singhal, R. S., & Tripathi, A. K. (2014). A comparative analysis among routing protocols based on factors affecting the Wireless Sensor Networks. 2014 International Conference on Issues and Challenges in Intelligent Computing Techniques (ICICT), 866–871. doi:10.1109/ICICICT.2014.6781395

Sikander, G. (2013). A Survey of Cluster-based Routing Schemes for Wireless Sensor Networks. The Smart Computing Review, 3(4), 261–275. doi:10.6029/smartcr.2013.04.005.

Taghikhaki, Z., Meratnia, N., & Havinga, P. J. M. (2013). A reliable and energy-efficient chain-cluster based routing protocol for Wireless Sensor Networks. 2013 IEEE Eighth International Conference on Intelligent Sensors, Sensor Networks and Information Processing, 248–253. doi:10.1109/ISSNIP.2013.6529797.

Tang, F., You, I., Guo, S., Guo, M., & Ma, Y. (2010). A chain-cluster based routing algorithm for wireless sensor networks. Journal of Intelligent Manufacturing, 23(4), 1305–1313. doi:10.1007/s10845-010-0413-4.

Villas, L. A., Boukerche, A., Ramos, H. S., Oliveira, H. A. B. F. De, Araujo, R. B. De, Alfredo, A., & Loureiro, F. (2013). DRINA : A Lightweight and Reliable Routing Approach for In-Network Aggregation in Wireless Sensor Networks, 62(4), 676–689.

Wei, C., Yang, J., & Gao, Y. (2011). Cluster-based routing protocols in wireless sensor networks: A survey. Proceedings of 2011 International Conference on Computer Science and Network Technology, 1659–1663. doi:10.1109/ICCSNT.2011.6182285.

Yang, J., Mao, Y., Yu, Q., & Leng, S. (2013). Rotation and chain-based energy saving routing protocol of wireless sensor network. 2013 International Conference on

Communications, Circuits and Systems (ICCCAS), 72–77. doi:10.1109/ICCCAS.2013.6765289.

Zhang, J., Wu, Q., Ren, F., He, T., & Lin, C. (2010). Effective Data Aggregation Supported by Dynamic Routing in Wireless Sensor Networks. 2010 IEEE International Conference on Communications, 1–6. doi:10.1109/ICC.2010.5502284.

Zheng, G., & Hu, Z. (2009). Chain Routing Based on Coordinates-Oriented Clustering Strategy in WSNs. 2009 International Symposium on Computer Network and Multimedia Technology, 2(1), 1–4. doi:10.1109/CNMT.2009.5374811.